

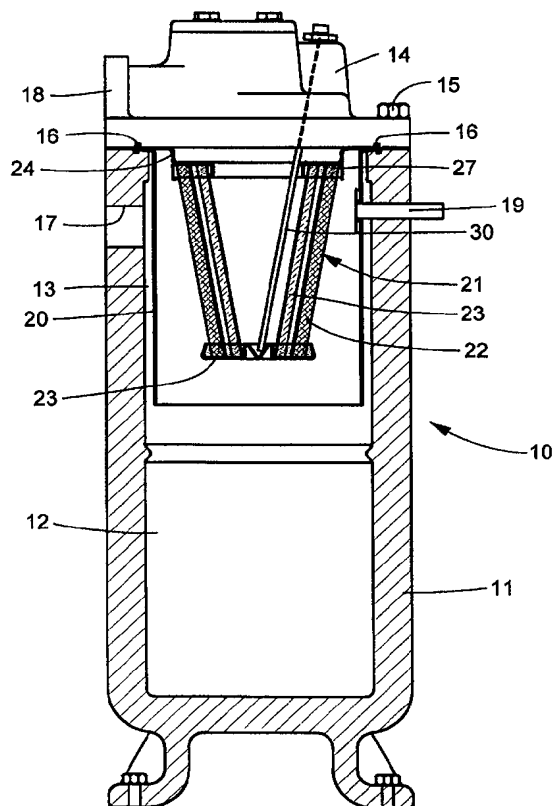


## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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<b>(21) International Application Number:</b> PCT/US99/04392  <b>(22) International Filing Date:</b> 1 March 1999 (01.03.99)  <b>(30) Priority Data:</b> 60/076,397 28 February 1998 (28.02.98) US  <b>(71) Applicant (for all designated States except US):</b> AIR-MAZE CORPORATION [US/US]; 115 East Steels Corners Road, P.O. Box 1459, Stow, OH 44224-0459 (US).  <b>(72) Inventors; and</b> <b>(75) Inventors/Applicants (for US only):</b> LINNERSTEN, Staffan, B. [SE/US]; 8624 Scenicview Drive, Broadview Heights, OH 44147-3476 (US). RADCLIFF, Christopher, D. [US/US]; 1921 Alliance Road, Deerfield, OH 44411-9710 (US). READ, Brian [GB/US]; 5019 Portland Cove, Stow, OH 44224-1593 (US). JODI, Wijadi [US/US]; 2319 Winter Parkway, Cuyahoga Falls, OH 44221-3769 (US).  <b>(74) Agent:</b> HILL, Stephen, A.; Rankin, Hill, Porter & Clark LLP, 700 Huntington Building, 925 Euclid Avenue, Cleveland, OH 44115-1405 (US).		<b>(81) Designated States:</b> AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).  <b>Published</b> <i>With international search report.</i>

**(54) Title:** CONICALLY SHAPED AIR-OIL SEPARATOR**(57) Abstract**

A liquid reservoir tank assembly (10) includes a gas-liquid separator (21), which has particular application as an air-oil separator. A tank body (11) has an open end, a portion of the tank body forming a liquid separation chamber (13), another portion of the tank body forming a liquid reservoir (12). A tank cover (14) covers the open end of the tank body, the tank body and the tank cover providing a gas inlet (17) and a gas outlet (18) with a gas flow through the separation chamber from the gas inlet to the gas outlet. The gas-liquid separator (21) is mounted in the separation chamber in the gas flow between the gas inlet and the gas outlet. The separator has a coalescing stage layer (22) and a drain stage layer (23) arranged radially symmetrically about an axis extending through the interior of the separator. One of the layers is positioned within the other of the layers. The coalescing stage layer is upstream of the drain stage layer. Each of the layers is generally frustoconical in shape whereby both of the layers are closer to the axis at one end than at the other end.



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# 1                                    **CONICALLY SHAPED AIR-OIL SEPARATOR**

## 2                                    **BACKGROUND OF THE INVENTION**

### 3                    1.        Field of the Invention

4                    This invention relates to filtering of liquids from gaseous streams, and more  
5                    particularly to air-oil separators such as those used to remove suspended oil in  
6                    compressor air discharge systems.

### 7                    2.        Description of the Prior Art

8                    Gas-liquid separators are used in various applications, but are most notably  
9                    used to separate oil from air. Air-oil separators are typically used where it is  
10                   necessary to remove suspended oil mist from an air stream, such as in the air  
11                   discharge systems of air compressors, vacuum compressors and refrigerant  
12                   compressors. The separator allows the discharged air to be used without the  
13                   contamination of the oil which has entered the air in the compressor, and provides  
14                   for the recovery of the oil so that it can be reused. The air-oil separator is typically  
15                   mounted in a housing or tank having a separation chamber through which the air  
16                   flows above an oil reservoir. The separator includes coalescing media through which  
17                   the discharge air passes while the oil is separated from the air flow. The coalescing  
18                   media is cylindrically shaped and is typically mounted vertically, that is, in which the  
19                   axis of the cylindrical coalescing media extends in a vertical direction. A shroud  
20                   may be provided within the separation chamber around the separator to slow the air

1 flow and provide a vertical direction to the air flow as it encounters the separator.  
2 The contaminated air usually enters the separation chamber from outside the air-oil  
3 separator and flows into the center of the separator where it then flows axially out  
4 of the separation chamber. As the air flows radially through the layers of the  
5 separator, the oil coalesces and collects in the interior of the separator where it can  
6 be syphoned off or drained into the reservoir, typically by means of a scavenging  
7 system, so that it can be reused. The flow directions may also be reversed in which  
8 contaminated air is introduced into the center of the air-oil separator and flows  
9 radially outwardly through the separator with the oil coalescing and collecting on the  
10 outside of the separator where it drains into a reservoir. An example of a prior art  
11 air-oil separator is shown in U.S. Patent No. 4,878,929.

12 The characteristics of the air flow and the size of the separator are limited by  
13 the cylindrical configuration of the separator. For example, where the air flows from  
14 the outside of the separator into the separator and a shroud is used around the  
15 separator in the separation chamber, the air must flow through the narrow annular  
16 chamber between the shroud and the outside of the separator before it enters the  
17 separator. This annular chamber has a constant cross section, but the air volume  
18 decreases through this chamber since some of the air enters the separator, and thus  
19 the air velocity decreases toward the top of the separator. Since sufficient clearance  
20 must be provided between the shroud and the outside of the separator, particularly  
21 at the bottom of this annular chamber, the size of the separator, and thus the effective  
22 surface area provided by the separator, is limited by the size of the shroud.

## 1 SUMMARY OF THE INVENTION

2 The present invention provides advantages over the prior art designs of air-oil  
3 separators that have not been realized heretofore. The present invention provides an  
4 air-oil separator which is generally conically shaped, providing a greater effective  
5 surface area over the same axial length than the prior art cylindrically shaped  
6 separators, since the generally conically shaped separator can be made with a larger  
7 diameter at the upper end while still providing sufficient clearance from the shroud  
8 at the lower end.

9 The air-oil separator of the present invention also provides a funnel type  
10 action to direct the flow of scavenged oil into a pool or reservoir where the oil can  
11 be more easily collected. This feature may be particularly advantageous when the  
12 separator is mounted in a horizontal orientation, that is, in which the axis of the  
13 separator extends horizontally. In this configuration, the prior art cylindrical  
14 separator collected oil along the bottom portion of the separator, and, since the  
15 separator extended horizontally, the oil tended to accumulate in this portion of the  
16 separator and not readily to drain off. Because the generally conically shaped  
17 separator of the present invention has a sloped bottom surface when mounted  
18 horizontally, the oil more readily drains from the separator and does not tend to  
19 collect in the bottom portion of the separator and inhibit separator performance. As  
20 a result, the separator has a longer life because it is not contaminated with  
21 accumulated oil.

22 The generally conically shaped air-oil separators of the present invention may  
23 be used in existing oil reservoir tank designs, thus eliminating the need for  
24 modification. They may also be used in an inventive new oil tank design which  
25 utilizes the advantages of the generally conically shaped separators.

1           These and other advantages are provided by the present invention of a liquid  
2   reservoir tank including a gas-liquid separator, comprising a tank body having an  
3   open end, a portion of the tank body forming a liquid separation chamber, another  
4   portion of the tank body forming a liquid reservoir; a tank cover covering the open  
5   end of the tank body, the tank body and the tank cover providing a gas inlet and a gas  
6   outlet with a gas flow through the separation chamber from the gas inlet to the gas  
7   outlet; and a gas-liquid separator mounted in the separation chamber in the gas flow  
8   between the gas inlet and the gas outlet, the separator comprising a coalescing stage  
9   layer and a drain stage layer arranged radially symmetrically about an axis extending  
10   through the interior of the separator, one of the layers positioned within the other of  
11   the layers, the coalescing stage layer being upstream of the drain stage layer, each of  
12   the layers being generally frusto-conical in shape whereby both of the layers are  
13   closer to the axis at one end than at the other end.

#### 14                           BRIEF DESCRIPTION OF THE DRAWINGS

15           FIG. 1 is a top plan view of an oil reservoir tank assembly with an air-oil  
16   separator according to the present invention.

17           FIG. 2 is a side sectional view of the oil reservoir tank assembly taken along  
18   line 2—2 of FIG. 1.

19           FIG. 3 is a detailed side sectional view of a portion of the air-oil separator of  
20   FIG. 2.

21           FIG. 4 is a top plan view of another oil reservoir tank assembly with an air-oil  
22   separator according to another embodiment of the present invention.

23           FIG. 5 is a side sectional view taken along line 5—5 of FIG. 4.

24           FIG. 6 is an end sectional view taken along line 6—6 of FIG. 5.

1           FIG. 7 is a detailed side sectional view of a portion of the air-oil separator of  
2   FIG. 5.

3           FIG. 8 is an end elevational view of yet another oil reservoir tank assembly  
4   with an air-oil separator according to another embodiment of the present invention.

5           FIG. 9 is a side sectional view taken along line 9—9 of FIG. 8.

6           DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

7           Referring more particularly to the drawings and initially to FIGS. 1 and 2,  
8   there is shown an oil tank assembly **10** according to the present invention. The tank  
9   assembly shown and described herein is only one of many arrangements in which the  
10   present invention may be used, and the tank and separation configuration may be  
11   altered significantly without affecting the present invention. The tank assembly **10**  
12   comprises a body **11** having a reservoir **12** formed at the bottom for collection of oil  
13   removed by in the oil separation process. The upper portion of the body **11** forms  
14   a separation chamber **13**. The top of the separation chamber **13** is enclosed by a tank  
15   cover **14** which is attached to the body **11** by a plurality of bolts **15** or other suitable  
16   fastening devices. A tank seal or gasket **16** is proved around the upper rim of the  
17   body **11**, between the body and the tank cover. Preferably, the tank seal **16**  
18   comprises an O-ring provided in a corresponding groove in the bottom of the tank  
19   cover **14** and another O-ring provided in a corresponding groove on the top of the  
20   upper rim of the tank body **11**. An air inlet **17** is provided on one side of the body  
21   **11** for air to enter the separation chamber **13**. The air flows from the separation  
22   chamber through a passage (not shown) in the tank cover **14** and through an air  
23   outlet **18** provided in the tank cover.

1           Within the separation chamber **13** is a generally cylindrical shroud **20** which  
2           diverts the incoming air flow from the air inlet **17** and causes the air to flow down  
3           and around the shroud. This provides a first stage air-oil separation, in that, large  
4           droplets of oil are separated by the abrupt change in air flow and these oil droplets  
5           fall into the reservoir **12**. A safety valve **19** is also provided in the body **11** extending  
6           through the shroud **20**. The safety valve **19** is a pressure relief valve which opens in  
7           the event that air pressure inside the shroud **20** increases above a predetermined  
8           level. The air flow then passes upwardly and axially inwardly, through an air-oil  
9           separator **21** comprising two generally conically shaped or generally frusto-conically  
10          shaped layers **22** and **23**.

11          The upstream layer **22** is a coalescing stage layer. The downstream layer **23**  
12          is a drain stage layer. In the embodiment shown in FIG. **2** in which the flow of air  
13          is from the outside to the inside of the air-oil separator **21**, the coalescing stage layer  
14          **22** is on the outside of the drain stage layer **23**, and the drain stage layer is inside the  
15          coalescing stage layer. The layers **22** and **23** are each preferably made of a molded  
16          or formed media so that they can be readily shaped into the desired conical or frusto-  
17          conical configuration. A pleated or wrapped media may also be used. The layers are  
18          comprised of any suitable combination of materials used in air-oil separation, such  
19          as fiberglass, polyester, polypropylene or metal, some of which may be pleated in  
20          a conventional manner, or which may be molded, formed, wrapped or otherwise  
21          shaped. As shown in FIG. **3**, the air-oil separator also preferably includes an outer  
22          wrap layer **25** on the exterior of the separator, and a support member **26** along the  
23          interior surface of the layer **22**.

24          The layers **22** and **23**, along with the layers **25** and **26**, are assembled into an  
25          air-oil separator unit **21** which is mounted in the separation chamber **13** within the  
26          shroud **20**. The lower ends of each of the layers **22**, **23**, **25** and **26** are set in a  
27          hardenable sealing material, such as urethane, epoxy or plastisol, which is molded

1 in place in a generally circular, lower connection plate **24**. The lower ends of the  
2 layers **22**, **23**, **25** and **26** are thus sealed to the lower connection plate **24**, and fluid  
3 is prevented from flowing into or out of the interior of the separator, except through  
4 the layers. Alternatively, in place of the metal connection plate **24**, the bottom ends  
5 of the layers **22**, **23**, **25** and **26** can be inserted into a plastic end cap made of a  
6 moldable plastic or elastic material such as polyurethane, which is molded in place;  
7 such a bottom end cap seals and holds the layers in position without a supporting  
8 metal connection plate. The upper ends of the layers **22**, **23**, **25** and **26** are set in a  
9 similar hardenable sealing material molded in an upper mounting plate assembly **27**,  
10 a portion of which extends radially outwardly from the layers. As shown in FIG. 3,  
11 the assembly **27** comprises an inverted trough portion **28** which surrounds the  
12 hardenable material in which the ends upper ends of the layers **22**, **23**, **25** and **26** are  
13 set, and a flange portion **29** which extends between the upper rim of the body **11** and  
14 the tank cover **14** and is secured in place by the connection of the tank cover on the  
15 tank body. The portions **28** and **29** are attached together, such as by welding. The  
16 upper ends of the layers **22**, **23**, **25** and **26** are thus sealed to the upper mounting plate  
17 **27**, and fluid is prevented from flowing into or out of the interior of the separator,  
18 except through the layers. Alternatively, in place of the upper mounting plate  
19 assembly **27**, an integrated upper end cap and flange may be formed in accordance  
20 with the disclosure of U.S. Patent Applications Serial Nos. 09/174,137 and  
21 09/174,139, the disclosures of which are hereby incorporated by reference in their  
22 entireties.

23 A scavenging tube **30** extends downwardly from the tank cover **14** into the  
24 separation chamber inside the drain stage layer **23**. Oil draining from the layer **23**  
25 can be withdrawn therefrom using the drain tube **30**.

26 Unlike the generally cylindrical air-oil separators of the prior art, the layers  
27 **22** and **23** of this invention are generally conically shaped, or frusto-conically

1 shaped, providing a larger amount of active surface area per axial length of the  
2 separator element, and providing a funnel type shape into which the scavenged oil  
3 may flow to be withdrawn through the tube **30** using a conventional oil scavenging  
4 system.

5 The tank assembly **10** shown in FIGS. **1-3** is designed to allow the incorpora-  
6 tion of the generally conically shaped air-oil separators in an otherwise convention-  
7 ally designed air-oil separator. The uniquely shaped separators may also be  
8 incorporated into an tank assembly designed specifically for their use, and such a  
9 tank assembly **110** is shown in FIGS. **4-7**. The tank assembly **110** has a body **111**,  
10 a reservoir **112**, a separation chamber **113**, a tank cover **114**, tank cover bolts **115**,  
11 a tank seal **116**, an air inlet **117**, an air outlet **118**, a safety valve **119**, a shroud **120**,  
12 and an air-oil separator **121** comprising a coalescing stage layer **122** and a drain stage  
13 layer **123**, each of which is generally similar to the body **11**, the reservoir **12**, the  
14 separation chamber **13**, the tank cover **14**, the tank cover bolts **15**, the tank seal **16**,  
15 the air inlet **17**, the air outlet **18**, the safety valve **19**, the shroud **20**, the air-oil  
16 separator **21**, the coalescing stage layer **22** and the drain stage layer **23** already  
17 described.

18 Unlike the layers **22** and **23** of FIGS. **2** and **3**, the coalescing stage layer **122**  
19 and the drain stage layer **123** are each made as separate modules which can be  
20 individually removed. Each of the elements **122** and **123** is mounted at each end in  
21 integrated seals which can be made of urethane or any suitable material. Unlike the  
22 air-oil separator **21** of FIGS. **1-3**, the air-oil separator is not assembled into an  
23 integrated unit. Instead, each of the elements **122** and **123** is separate and can be  
24 individually replaced as needed. The drain stage element **123** is self supporting.  
25 The coalescing stage element **122** is mounted in a frame the bottom of which is  
26 attached to a scavenge flow drain tube **130** which extends through the reservoir **112**.  
27 At the bottom of the tube **130** is a scavenged oil return port **132**.

1           While the air-oil separator of this invention has been described with reference  
2   to an oil tank having an outside-in air flow, that is, in which the air flows radially  
3   from outside the separator to the interior of the separator, it should be understood  
4   that the separator provides equal advantages when the air is flowing the opposite  
5   direction. Instead of air entering the oil tank assembly **10** through the inlet **17** and  
6   exiting through the outlet **18**, the air flow may be reversed with the air entering the  
7   oil tank through the passage **18** and exiting through the passage **17**. The air-oil  
8   separator provides the same advantages under these circumstances. Likewise, while  
9   the air-oil separator of this invention has been described with reference to a separator  
10   which is mounted vertically in an oil tank assembly, that is in which the axis of the  
11   separator extends vertically, the advantages of the separator of this invention can also  
12   be realized in configurations in which the separator is mounted horizontally.

13           FIGS. **8** and **9** shows a tank assembly **210** which incorporates both inside-out  
14   air flow and a horizontally mounted air-oil separator. The tank assembly **210** has a  
15   body **211**, a reservoir **212**, a separation chamber **213**, a tank cover **214**, tank cover  
16   bolts **215**, a tank seal **216**, a shroud **220**, and an air-oil separator **221** comprising a  
17   drain stage layer **223** and a coalescing stage layer **222**, each of which is generally  
18   similar to the body **11**, the reservoir **12**, the separation chamber **13**, the tank cover  
19   **14**, the tank cover bolts **15**, the tank seal **16**, the shroud **20**, the drain stage layer **23**  
20   and the coalescing stage layer **22** already described.

21           Unlike the previously described embodiments of the invention, the separator  
22   of FIGS. **8** and **9** uses an inside-out flow, with an air inlet **217** is provided in the tank  
23   cover **214** and an air outlet **18** is provided in the tank body **211** on the top of the  
24   tank. Therefore, the coalescing stage layer **222** of the separator is provided inside  
25   the drain stage layer **223**, and the oil drains from the separator into the reservoir **212**.  
26   Since the generally conically shaped air-oil separator **221** of this embodiment does  
27   not have layers which extend completely horizontally, oil does not tend to

1     accumulate along the bottom of the separator. Instead, the sloped configuration of  
2     the bottom of the separator facilitates the drainage of the oil from the separator so  
3     that it falls more readily into the reservoir **212**.

4             While the layers of the air-oil separator of this invention have been described  
5     as being generally conical or generally frusto-conical, this is intended to include  
6     layers which have pleats or soft pleats or ribs, and thus do not have smooth inner or  
7     outer surfaces. It is contemplated that layers having such pleats or ribs which are  
8     then generally formed into a conical or frusto-conical shape, rather than a cylindrical  
9     shape, would realize the advantages of the present invention.

10            Other variations and modifications of the specific embodiments herein shown  
11     and described will be apparent to those skilled in the art, all within the intended spirit  
12     and scope of the invention. While the invention has been shown and described with  
13     respect to particular embodiments thereof, these are for the purpose of illustration  
14     rather than limitation. Accordingly, the patent is not to be limited in scope and effect  
15     to the specific embodiments herein shown and described nor in any other way that  
16     is inconsistent with the extent to which the progress in the art has been advanced  
17     by the invention.

## CLAIMS

What is claimed is:

- 1           **1.**     A liquid reservoir tank assembly including a gas-liquid separator,  
2     comprising:  
3           a tank body having an open end, a portion of the tank body forming a liquid  
4           separation chamber, another portion of the tank body forming a liquid  
5           reservoir;  
6           a tank cover covering the open end of the tank body, the tank body and the  
7           tank cover providing a gas inlet and a gas outlet with a gas flow  
8           through the separation chamber from the gas inlet to the gas outlet; and  
9           a gas-liquid separator mounted in the separation chamber in the gas flow  
10          between the gas inlet and the gas outlet, the separator comprising a  
11          coalescing stage layer and a drain stage layer arranged radially  
12          symmetrically about an axis extending through the interior of the  
13          separator, one of the layers positioned within the other of the layers,  
14          the coalescing stage layer being upstream of the drain stage layer, each  
15          of the layers being generally frusto-conical in shape whereby both of  
16          the layers are closer to the axis at one end than at the other end.

1           2.       A liquid reservoir tank assembly as in claim 1, wherein the axis of the  
2       separator extends vertically, the separator is suspended in the separator chamber, and  
3       the layers are closer to the axis at the bottom of the separator than at the top.

1           3.       A liquid reservoir tank assembly as in claim 1, wherein the axis of the  
2       separator extends horizontally.

1           4.       A liquid reservoir tank assembly as in claim 1, wherein the gas flows  
2       from the exterior of the gas-liquid separator radially inwardly toward the interior axis  
3       of the separator, and the drain stage layer is inside the coalescing stage layer.

1           5.       A liquid reservoir tank assembly as in claim 1, wherein the layers are  
2       separately removable from the tank.

1           6.       A liquid reservoir tank assembly as in claim 1, comprising in addition  
2       a shroud around the separator in the separation chamber.

1           7.     A liquid reservoir tank assembly as in claim 6, wherein the gas inlet is  
2     along a side of the tank body adjacent to the shroud.

1           8.     A liquid reservoir tank assembly including a gas-liquid separator,  
2     comprising:  
3           a tank body having an open end, a portion of the tank body forming a liquid  
4           separation chamber, another portion of the tank body forming a liquid  
5           reservoir;  
6           a tank cover covering the open end of the tank body; and  
7           a gas-liquid separator mounted in the separation chamber, the separator  
8           comprising a coalescing stage layer and a drain stage layer each  
9           arranged radially symmetrically about a vertical axis, one of the layers  
10          positioned within the other of the layers, the coalescing stage layer  
11          being upstream of the drain stage layer, each of the layers being  
12          generally frusto-conical in shape whereby both of the layers are closer  
13          to the axis at lower end than at the upper end.

1           9.     A liquid reservoir tank assembly as in claim 8, wherein the gas flows  
2     from the exterior of the gas-liquid separator radially inwardly toward the interior axis  
3     of the separator, and the drain stage layer is inside the coalescing stage layer.

1           **10.**    A liquid reservoir tank assembly as in claim **8**, wherein the layers are  
2   separately removable from the tank.

1           **11.**    A liquid reservoir tank assembly as in claim **8**, comprising in addition  
2   a shroud around the separator in the separation chamber, the gas flowing between the  
3   inside of the shroud and the outside of the separator before passing through the  
4   separator.

1           **12.**    A liquid reservoir tank assembly as in claim **11**, wherein the gas inlet  
2   is along a side of the tank body adjacent to the shroud, the gas flowing from the inlet  
3   around the shroud before passing through the separator.

1           **13.**    A liquid reservoir tank assembly as in claim **8**, comprising in addition  
2   scavenging tube extending into the interior of the separator for the removal of liquid  
3   accumulating therein.

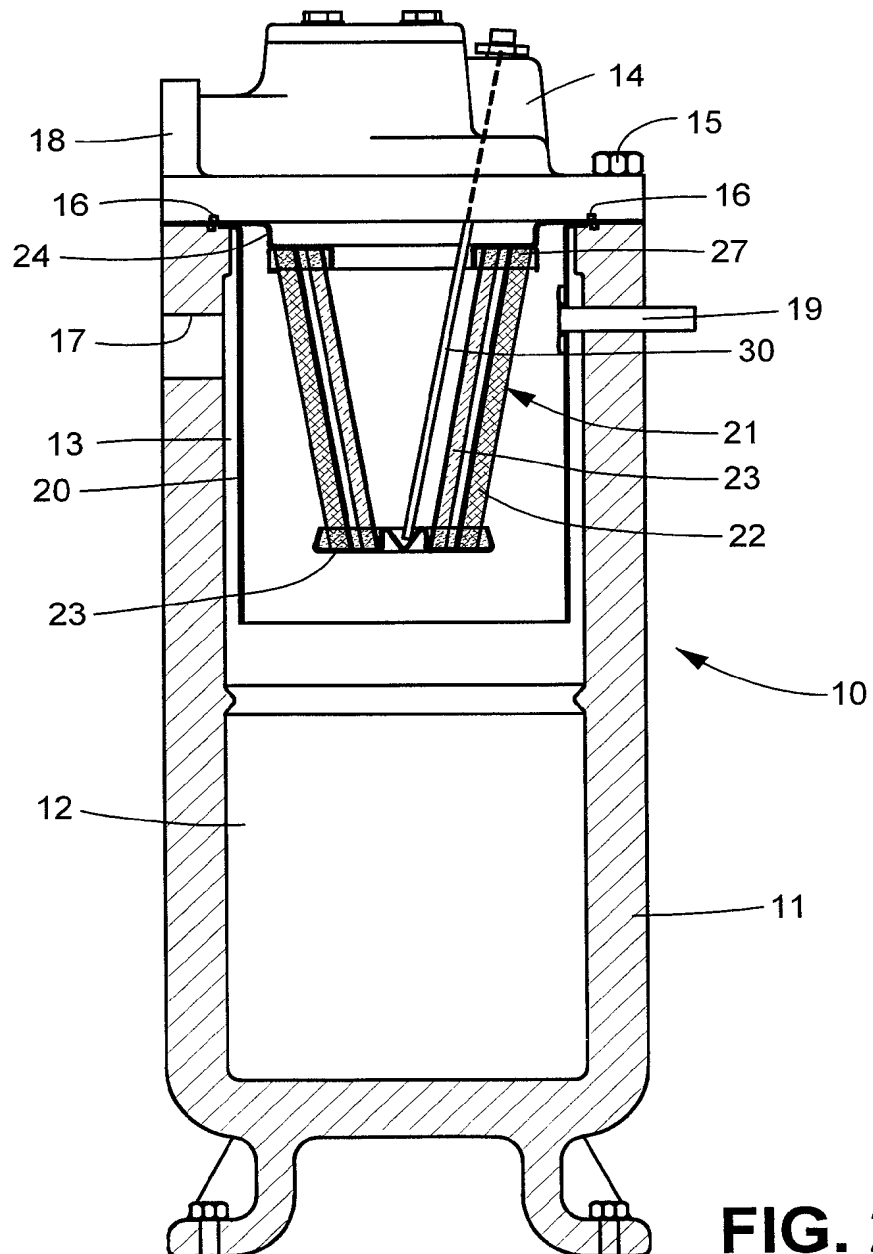
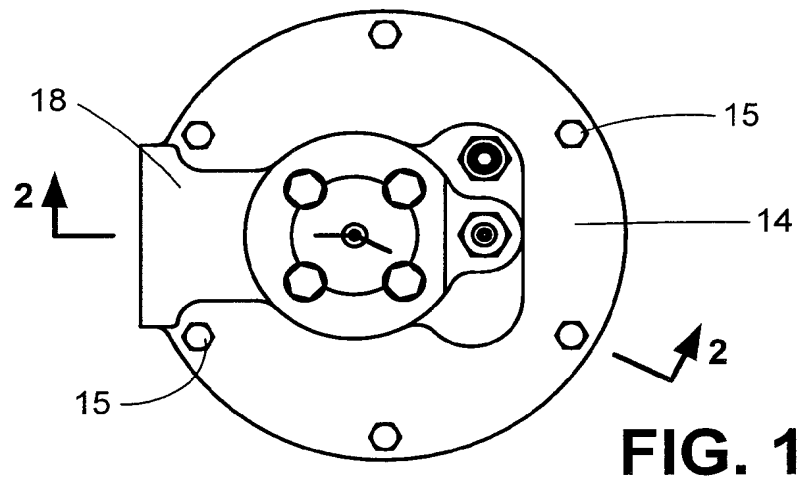
1           **14.**    A liquid reservoir tank assembly as in claim **8**, comprising in addition  
2   drain tube extending downwardly from the interior of the separator for the drainage  
3   of liquid accumulating therein.

1           **15.**   A liquid reservoir tank assembly including a gas-liquid separator,  
2   comprising:  
3           a tank body having an open end, a portion of the tank body forming a liquid  
4           separation chamber, another portion of the tank body forming a liquid  
5           reservoir;  
6           a tank cover covering the open end of the tank body; and  
7           a gas-liquid separator mounted in the separation chamber, the separator  
8           comprising a coalescing stage layer and a drain stage layer each  
9           arranged radially symmetrically about a horizontal axis, one of the  
10          layers positioned within the other of the layers, the coalescing stage  
11          layer being upstream of the drain stage layer, each of the layers being  
12          generally frusto-conical in shape whereby the layers are closer to the  
13          axis at one end than the other end.

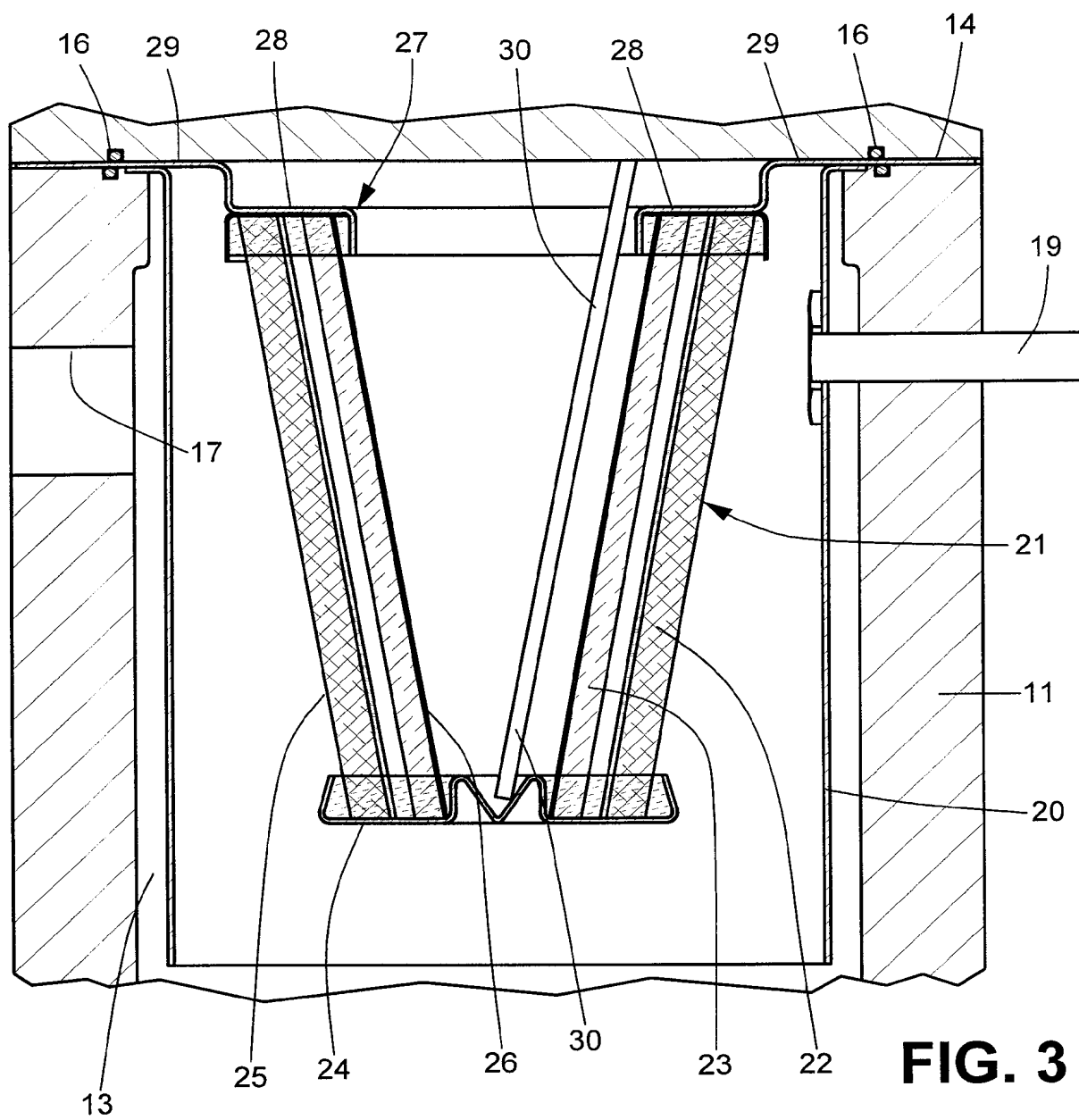
1           **16.**   A liquid reservoir tank assembly as in claim **15**, wherein the gas flows  
2   from the interior of the gas-liquid separator radially outwardly toward the exterior  
3   of the separator, and the coalescing stage layer is inside the drain stage layer.

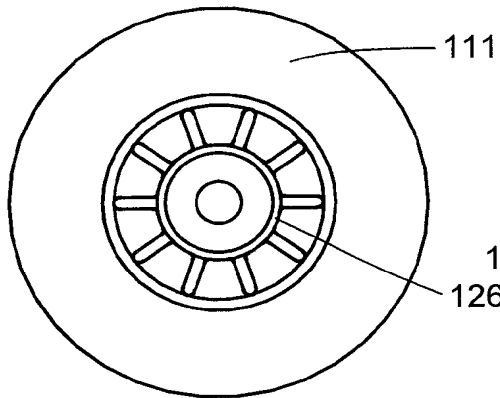
1           **17.**   A liquid reservoir tank assembly as in claim **15**, comprising in addition  
2   a shroud around the separator in the separation chamber.

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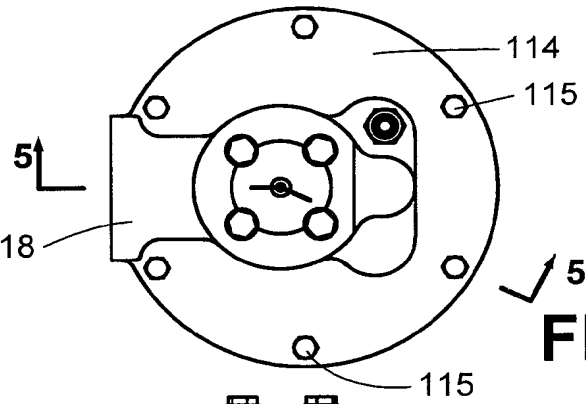


**FIG. 2**

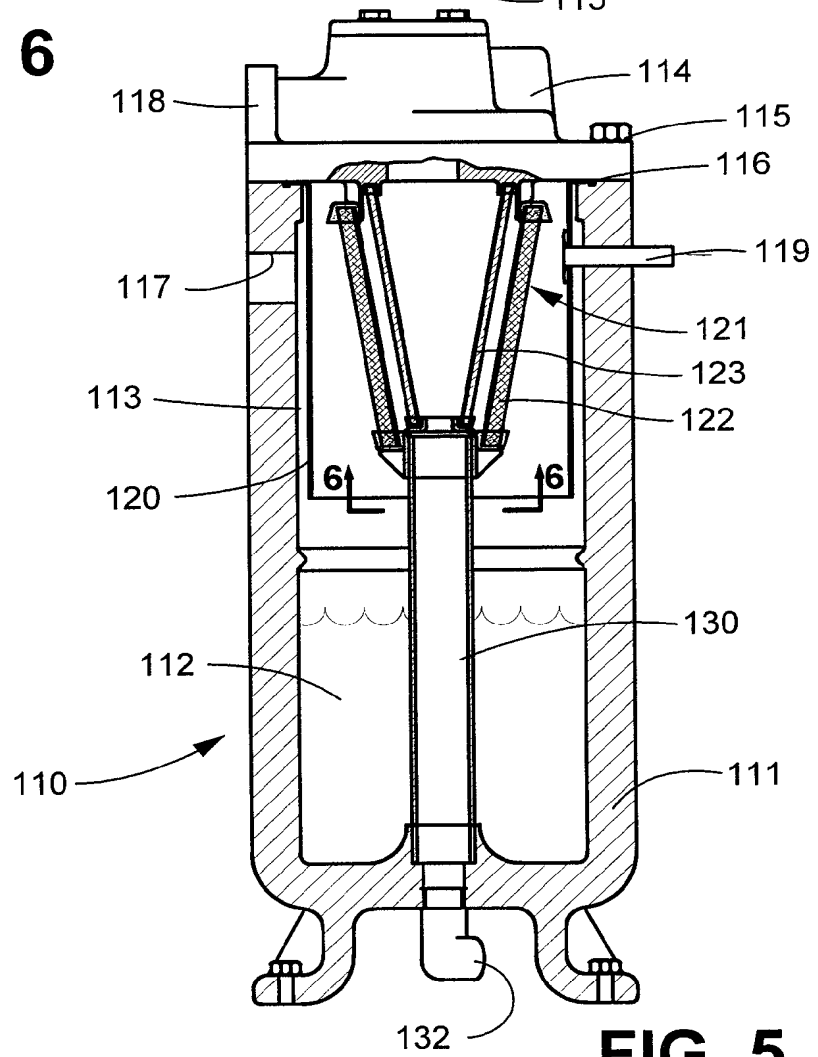




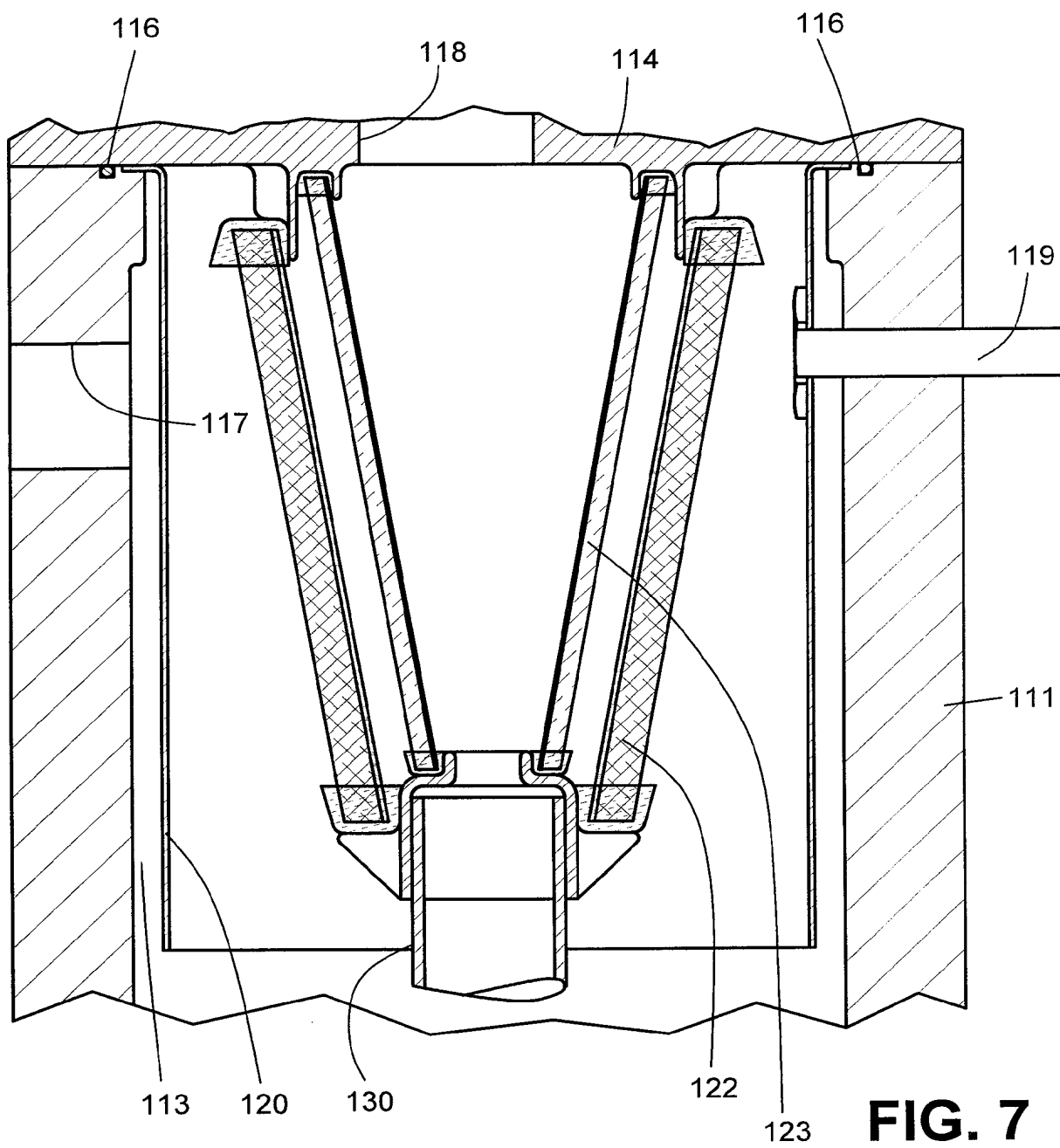
**FIG. 6**

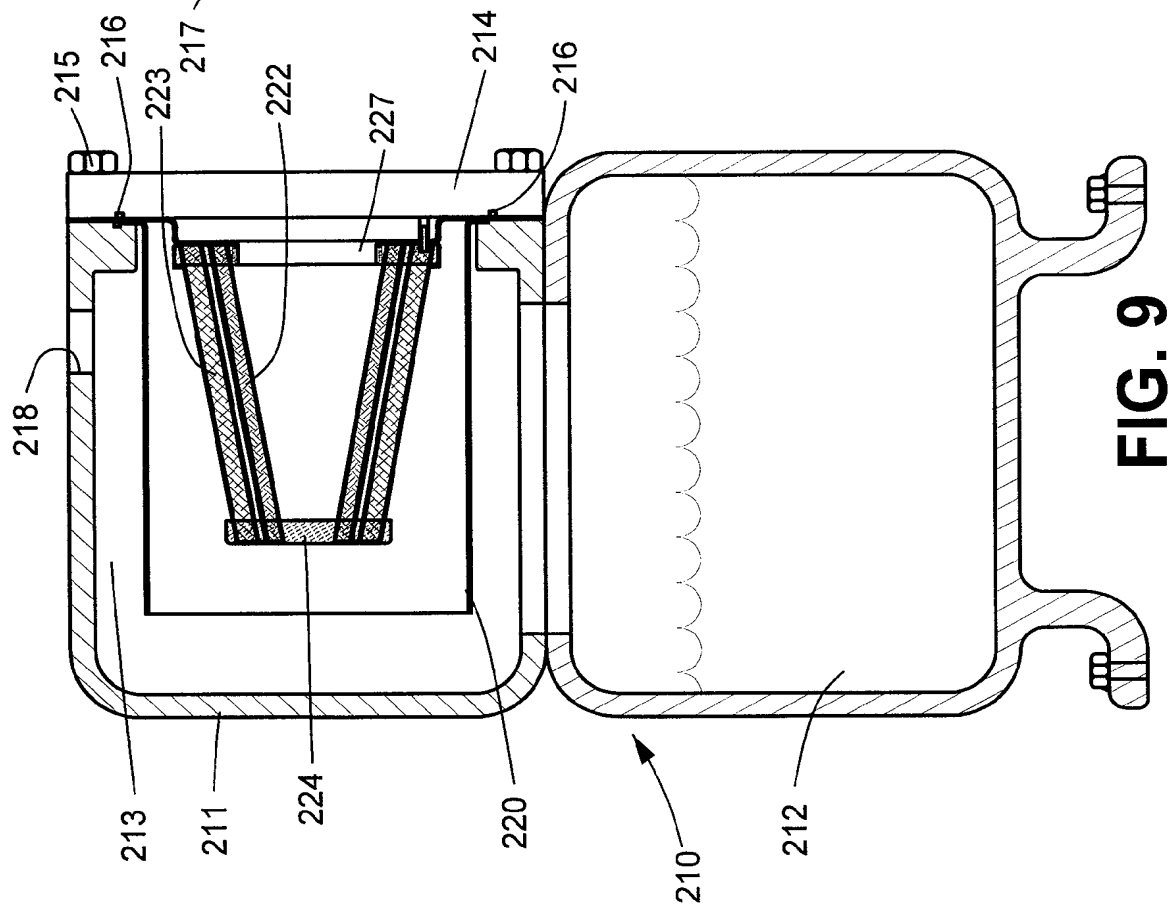
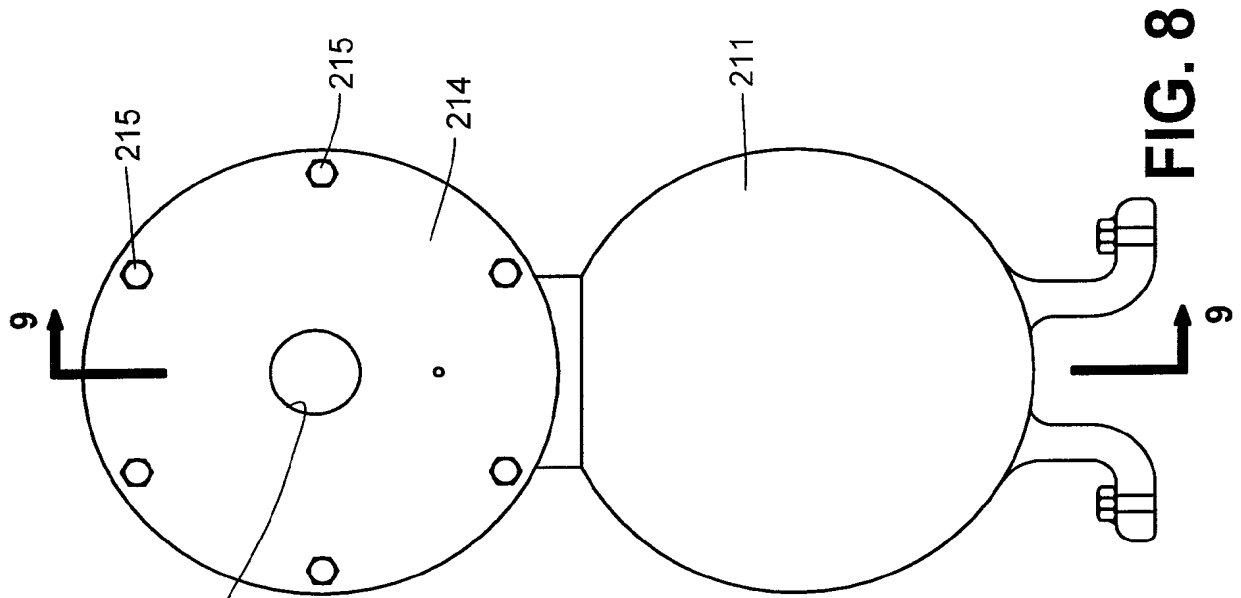


**FIG. 4**



**FIG. 5**





## INTERNATIONAL SEARCH REPORT

International application No.

PCT/US99/04392

**A. CLASSIFICATION OF SUBJECT MATTER**

IPC(6) :BO1D 46/24

US CL :55/327,330,395,423,486, DIG. 17

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 55/327,330,395,423,486, DIG. 17,319,320,323,392,421,429,466,487

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

NONE

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

NONE

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 1,922,688 A (KAMRATH) 15 August 1933.	1-17
A	US 2,095,586 A (ALGARD) 12 October 1937.	1-17
A	US 3,085,381 A (SOBECK) 16 April 1963.	1-17
A	US 3,364,658 A (WALKER) 23 January 1968.	1-17
A	US 4,878,929 A (TOFSLAND et al.) 07 November 1989.	1-17
A	US 5,129,923 A (HUNTER et al.) 14 July 1992.	1-17



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
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"P" document published prior to the international filing date but later than the priority date claimed	

Date of the actual completion of the international search

08 APRIL 1999

Date of mailing of the international search report

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